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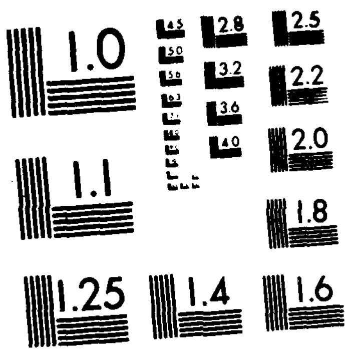

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The first year of the grant was spent in setting up the laboratory, and in starting research on a number of different projects. All are concerned with the visual processing of information in the perception of objects. A series of experiments has explored the perception of conjunctions of features, attempting to determine what makes this difficult or easy. A new method (detection of apparent motion) was tested and a modification of feature-integration theory was developed to accommodate the new results. Other projects have been concerned with the coding of features, finding evidence for modularity, testing the level of abstraction at which features (such as orientation) are coded, the different "media" which support the coding of shape, and the space in which they are represented (retinal or three-dimensional). Another project has probed the effects of perceptual learning with extended practice at detecting particular sets of targets; the results suggest that automatization in search is highly specific to the practiced task and has little effect on other perceptual tests. Six graduate students are at present, working on projects (pto)

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VISUAL INFORMATION PROCESSING IN THE PERCEPTION OF FEATURES AND OBJECTS

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Prepared for
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Summary

The first year of the grant was spent in setting up the laboratory, and in starting research on a number of different projects. All are concerned with the visual processing of information in the perception of objects. A series of experiments has explored the perception of conjunctions of features, attempting to determine what makes this difficult or easy. A new method (detection of apparent motion) was tested and a modification of feature-integration theory was developed to accomodate the new results. Other projects have been concerned with the coding of features, finding evidence for modularity, testing the level of abstraction at which features (such as orientation) are coded, the different "media" which support the coding of shape, and the space in which they are represented (retinal or three-dimensional). Another project has probed the effects of perceptual learning with extended practice at detecting particular sets of targets; the results suggest that automatization in search is highly specific to the practiced task and has little effect on other perceptual tests. Six graduate students are at present, working on projects wholly or partly supported by the grant.

Professional personnel

Anne Treisman, Principal Investigator
Sharon Sato, Technical assistant (50% time)
Ephram Cohen, Programmer (15% time)
Stephanie Muth, now replaced by Sarah Preisler, Clerical assistant (25% time)

Graduate Students supervised

Gail Musen, working for PhD. thesis
Alfred Vieira, second year project. Worked as R.A. supported by the AFOSR grant for 6 months.
Marcia Grabowecky, M.A. thesis (at University of British Columbia); now working on second year project at Berkeley
Kathy O'Connell, first year project. Worked as R.A. on grant for 1 month.
Elizabeth Beiring, first year project. Worked as R.A. on grant for 1 month.
Frances Kuo, first year project. Worked as R.A. on grant for 2 months.

Organisation and administration

The grant from AFOSR began in January, 1987. I spent some time initially setting up the laboratory and organizing the day-to-day running. The laboratory is shared with Daniel Kahneman. It consists of a central area for meetings, discussions, word processing and programming, four experimental rooms, and two offices for the technical assistant and the graduate students. It contains six IBM AT's, three color graphics systems and an HP black and white vector display, so that up to four different experiments can be run at once. The programming for running on-line experiments and collecting and analysing behavioral data took some time to organize, but, thanks to Ephram Cohen, Sharon Sato, and Alfred Vieira, it is now running extremely smoothly and well. We set up a panel of about 80 volunteer subjects, so experiments are now easy to organize and run. Sharon Sato controls the day-to-day running of the laboratory and coordinates the activities of the ten or eleven graduate students, and the clerical assistants, now working in it, as well as programming and running experiments.

Research completed and in progress

We have a number of research projects, either completed or in progress. All relate to the visual processing which results in the perception of objects; some explore the early stages of feature analysis, using visual search as a tool to identify properties that appear to be coded automatically and in parallel spatially across the field. Others investigate the role of attention in conjoining these features to form organized multidimensional objects, and attempt to determine the nature of the representation which underlies our conscious experience and our memory of these perceived objects.

The research can be classified under four main headings: (1) feature analysis in early vision; (2) the coding of conjunctions of features; (3) the effects of spatial attention in vision; (4) memory for visual stimuli. This report will outline the experiments that have been initiated or completed in each of these areas.

I. Feature Analysis

The questions studied have concerned the nature of the visual coding that occurs early, automatically and in parallel. We look for converging operations to tap these early levels of analysis. So far, we have used three different paradigms - search, texture segregation and apparent movement. We have also tried to probe the nature of the features extracted in these tasks, testing the level of abstraction at which orientation is defined, the possible equivalence of subjective and real contours, and of features of shape defined in different media (luminance, color, stereoscopic depth, differences in motion, etc.), and finally the question whether feature coding is done in retinal or three-dimensional space.

(1)Visual search and modularity

Several experiments used visual search tasks with targets defined by simple features that had been previously found to be coded in parallel (orientation, color, size, and the presence of a gap in rectangular bars). The factors we varied were the number of different types of distractors present in any display and the number of different types of targets that were relevant on any trial. We argue that heterogeneity of the distractors should not affect search if the target is detected by analysis within a specialized module coding the relevant target-defining feature and if the distractors vary on other "separable" dimensions coded by other independent modules. This is what we found for targets defined by color, orientation, and size. Conversely, we argue that if feature analysis is indeed modular, detection of a target might be slower when the relevant module is not specified in advance, so that the subjects are forced to search for the odd one out. Again this is what we found (see pages 12-15 in the paper on "Features and objects: the fourteenth Bartlett memorial lecture"). The results conflict with the hypothesis, proposed by Beck (1982), by Sagi and Julesz (1987), and implied by Marr (1982), that early stages of visual coding result in a single global representation pooling information about boundaries and discontinuities on all dimensions of variation.

(2)Texture segregation

The results described above suggested that boundaries between areas containing different elements might be separately defined within different specialized feature modules. If so, displays in which different boundaries are defined by features on different dimensions might be harder to parse with brief presentations than displays in which all boundaries are defined by features on the same dimensions. We have begun to test this possibility using displays in which one, two, or three boundaries between homogeneous groups of elements are defined either all by color, or all by shape, or some by color and some by shape. So far, however, the results provide no support for the hypothesis; the difficulty seems to be determined simply by the least discriminable of the boundaries present. We plan further experiments to see why this should be and whether it will require a modification of the theory.

(3)Apparent movement

Apparent movement is seen when one or more elements are presented successively in different locations at the right temporal intervals. When more than one element is present, the perception of apparent movement requires that a match be made between elements in the first and second fields to determine which is seen to move where. This is known as the "correspondence problem" (Ullman, 1979). Since apparent motion is determined at short intervals and globally for a whole display, it is probably an early visual process, dependent on preattentive coding. It might therefore offer converging evidence for the psychological reality of particular perceptual features (Treisman, 1986). Ramachandran (1987) used this logic to show that shape-from-shading is available to be matched across successive displays and to generate apparent motion of a group of convex shapes against a background of concave shapes. We have adapted his method to test whether the correspondence required for apparent motion can be based on color, on orientation and on size. A subgroup of bars is embedded in a display containing two other types of bars that differ from them in color or size or orientaton. The target group is shifted either as a whole, preserving all its spatial relations, or piecemeal (in different directions or distances), in a second display. The background items are shifted much less and in randomly selected directions, simply to eliminate cues from offsets and onsets. Subjects are asked to discriminate coherent from incoherent motion of the target group. The results so far suggest that both color and orientation can provide an input to the matching process that determines apparent motion, provided that they are highly discriminable. Size is less effective, although performance was better than chance, especially when the targets were larger than the background. When the target group was defined by a value intermediate between two types of distractors (medium-sized against large and small distractors, vertical against left and right-tilted distractors, grey against red and green distractors) performance was very poor for most subjects. Even here, however, a few subjects may be able to perform well above chance. This research is still in progress.

<u>(4)Different media (channels) for features of shape</u>

Some features characterize the shapes or boundaries of areas defined by discontinuities in another feature. The most commonly studied features are the orientation, straight vs curved lines and size of shapes whose boundaries are defined by luminance contrast. Cavanagh (1987) has also studied properties of shapes where the shapes are themselves defined by contrasts in depth (stereopsis), direction of motion, color (at isoluminance), and spatial frequency of texture elements, as well as by luminance. We have recently collaborated (together with Arguin) on a study of visual search for targets defined in each of these different media and differing from the distractors in their size or orientation. We find parallel detection of targets (i.e. search times independent of the number of distractors) when the targets are defined by tilt or size in each of these different media, and evidence of the same search asymmetry that we previously found in the luminance domain between tilted targets among vertical distractors and vertical targets among tilted distractors. The similarity of the search data across all these different media defining the stimuli suggests that coding for the features that distinguish shapes may be replicated at many different levels of visual processing (see pages 44-50 of the paper "Features and objects : the fourteenth Bartlett memorial lecture")

<u>(5)Features in two-dimensional or three-dimensional space?</u>

A related question is whether the features of shape that are coded preattentively in these search tasks are defined in retinal or in real world spatial co-ordinates. Frances Kuo and I have used the search asymmetry previously discovered (Treisman & Gormican, 1988) between ellipses and circles to try to answer this question. We presented a target square among distractor rectangles or vice versa.

When the displays are presented in the frontal plane, we obtain the same asymmetry as with circles and ellipses: rectangles are found more easily among squares than the reverse. We are now testing subjects with the same displays at a 45° angle to the line of sight, with displays that produce the same retinal shapes (squares and rectangles) as those in the frontal plane but that are presented at a 45° angle, and finally with displays that are presented in the frontal plane but reproduce the retinal shapes of the squares and rectangles seen at an angle of 45°.

(6)Subjective contours as features ?

Van der Heydt, Peterhans and Baumgartner (1984) have shown that single units in area V_2 of cat cortex respond to subjective contours. It seems possible, then, that subjective contours are coded automatically in early vision. Marcia Grabowecky and I have begun two tests of this hypothesis. (a) In a visual search task, we present a target subjective triangle among "pacman" triples that do not create subjective triangles (see Figure 1) and the converse - a pacman triple as target among subjective triangles, to see if the triangle pops out while the non-triangle pacman triples do not. The results show no pop-out and no search asymmetry with these stimuli. Both give apparently serial search with about the same slope against display size. Informal observation suggests that not only focused attention but also visual fixation is necessary for the subjective contours to emerge. (b) We are looking for apparent movement of a subjective triangle between two pacman triples (see Figure 2) and testing whether the sensation of motion disappears when more stimuli are present and/or when eye movements are prevented. Again, the results so far suggest that the illusory triangle is seen to move when it receives attention and the eyes can follow it, but not otherwise. If these results hold up, they suggest that the coding of subjective contours is not automatic, but depends on attention. The cells in V_2 found by Van der Heydt may be part of a recurrent pathway with feedback from higher visual centers in the cortex.

(7)The coding of orientation

Kathy O'Connell and I have been exploring the nature of the representation of orientation formed by the visual system. I had previously shown that the code for orientation seems to be the same for lines and for dot pairs (Treisman, 1985). The evidence was that search for a line tilted left was serial in a display containing lines tilted right and dot pairs tilted left, as if the target were defined by a conjunction of the "medium" (line vs dots) and orientation (left vs right tilt). The fact that the target orientation was shared by the distractor dot pairs prevented the parallel detection that I had obtained with search for the same target in a background of lines and dot pairs that all tilted right. We ran an experiment to see whether the same result would be found when the dot pairs consisted of one black and one white dot on a grey background (which unlike the black dot pair would give no output from the oriented bar detectors described by Hubel and Wiesel, 1968). The results suggested that these distractors interfere much less, as if the code for orientation is different in these bi-contrast stimuli. It is possible, however, to code the orientation of bi-contrast dot pairs in parallel. A target pair tilted left will "pop-out" of a background of pairs tilted right. Orientation must therefore be codable by detectors other than the Hubel and Wiesel cells. We are now running similar experiments to see whether the code for orientation is shared between lines and edges and between either lines or edges and subjective contours produced by abutting lines (see Figure 3). We are also testing whether the orientation of the motion path of a dot is coded by the same functional detectors as the orientation of lines.

II. Conjunctions and Selective Attention

Most objects we perceive are distinguished not by simple features but by how those features are conjoined. My previous research (e.g. Treisman & Gelade, 1980; Treisman & Schmidt, 1982) suggested that focused attention is needed to conjoin features. This hypothesis has recently been challenged, first by Nakayama (1986, in preparation) and then by Wolfe, Franzel, and Cave (1987, in preparation). Both these research groups used very highly discriminable features in a conjunction search paradigm, and found only small effects of display size or no effect at all. Targets defined by conjunctions of some very salient features appear to "pop-out" in parallel. I have been trying to find out more about the conditions that allow parallel access to conjunction information and to see what modifications to my theory will be needed to account for these results.

1) Search for conjunction targets

In the first experiment, I used as stimuli bars with conjunctions of each possible pair of values on the following dimensions - color (pink vs green), size (big vs small), orientation (45° left vs 45° right) and direction of motion (vertical vs horizontal oscillation). I will use the initial letters as shorthand to define the possible stimuli; so PSVL means pink, small, vertical motion, left tilt. Pairs of dimensions were tested with neutral values on the other two dimensions; the neutral values were grey, medium size, no motion, vertical orientation. So, for example, search for a conjunction of color and orientation might use a PL target among PR and GL distractors, all being stationary, medium size bars. The mean search rates are given in Table 1, together with the search rates for each feature on its own (i.e. conjoined with the same neutral values on all the other dimensions). The slopes were all quite linear against the display sizes that we tested (4, 9, and 16, with density and mean distance from fixation equated across all displays).

Table 1

Mean slopes for target present (left) and target absent (right) with each combination of dimensions

	Size	Color	Motion
Orientatation			
Color	6.9, 12.2		
Motion	8.6, 17.9	9.8, 20.2	
Orientation	12.9, 25.8	16.6, 27.5	14.0, 43.5
Single Feature	1.6, 0.2	0.8, -1.3	-0.5, 0.2
0.2, 0.3			

In every conjunction search condition, the slopes were significant, whereas for feature search none was significantly greater than zero. However most of the search rates are much faster than we had previously found. For example, 7 of the 16 subjects detected the larger target when it was present in the MS and CS conditions at latencies that would imply under 5ms per item if search were serial. It seems more likely that search is parallel either over groups of items or occasionally over the whole display.

Two points are worth discussing. One, already noted by Nakayama, is that the difficulty cannot be predicted on the basis of what is known of physiological coding in early vision. For example, size or spatial frequency and orientation are typically detected by the same single units in areas V_1 and V_2, yet here they give steeper slopes than color and motion, which seem physiologically most separable.

A second point that emerges clearly is that the difficulty cannot be predicted on the basis of any one dimension alone. For example, the search rates for conjunctions involving color were 12.2, 20.2, and 27.5, although the same colors in the same amounts were used in each case. It seems unlikely then that the difficulty depends only on how effectively the display can be segregated on the basis of any single feature. Both features in the relevant conjunction seem to contribute, and to contribute independently, since their effects are close to being additive. For example, values of 5ms per item for size, 8 for color, 13 for motion, and 22 for orientation would give quite accurate predictions of the mean search rates, (estimated from the mean of the negative and twice the positive slopes).

My colleagues and I have suggested that search functions with different slopes may reflect serial search directed to groups containing different numbers of items (Treisman & Souther, 1985; Treisman & Gormican, 1988). The larger the group, the higher the search rate. The group size would be determined by the signal-to-noise ratio of the pooled signal within the group, which in turn varies with the discriminability of the target and the distractors. When these differed only quantitatively on a shared dimension (e.g. length, degree of closure, or contrast), we found linear functions with different slopes.

This model can be extended to account for conjunction search with one further assumption. Wolfe et al (1987) have suggested that search for conjunctions of highly discriminable features may be achieved by inhibiting the distractors on the basis of the feature that differentiates them from the target (without any need to conjoin their features). I have also suggested that inhibition from the feature map for a non-target feature could help to segregate the irrelevant areas to be scanned with focused attention within the master-map of locations (Treisman, 1988). The more effective the inhibition from a particular feature map, the larger may be the group of non-inhibited items that can be checked in parallel. This would follow from the increase in signal-to-noise- ratio differentiating the non-inhibited target from the inhibited distractors. Once the group that contains the target has been found, attention would focus in onto the target to check that it does indeed have the correct conjunction of features. The stronger the inhibition, the flatter the search functions should be. Wolfe et al. showed that when distractors differ from the target in two features rather than one (i.e. the target is a triple conjunction, such as PBV among distractors PSH, GBH, and GSV), search rates become very high or even completely independent of display size. At this extreme, attention could be directed to the whole display as one large group because each distractor would be inhibited from two different feature maps.

2)Apparent movement and conjunctions of stimuli

In order to test the suggestion that feature inhibition might allow parallel segregation and global attention to a whole group of conjunction stimuli when the distractor features are highly discriminable, we used the apparent motion paradigm outlined in section I(3). The distractors and the target items whose motion was to be judged coherent or not were defined by the same features of color, size, and orientation as the ones used in the conjunction search experiments of section II(1). The research is still in progress, but the results so far suggest that only color-size conjunctions allow the detection of apparent motion at much better than chance levels. The results were 37% error for color-size, which is significantly less than 50%, 42% for color-orientation and 44% for size-orientation, neither of which differed significantly from the chance value of 50%. Color-size conjunctions also gave considerably higher search rates in the previous experiment (12ms per item compared to 28 and 26ms per item). Again, there seems to be a convergence between these two tests of early coding - parallel matching in apparent motion and target salience in search.

3)Perceptual learning

Alfred Vieira and I have been exploring the effects of prolonged practice at search for conjunctions of shape elements on other measures of visual processing. We completed one study of automatization in letter search with four subjects who each had 16 sessions of practice searching for three arbitrarily selected letters (EXR or TVQ) in displays of 1, 2 and 4 other letter distractors. We compared their performance before and after practice, both on the practiced targets and on the control targets (The practiced targets for 2 subjects were the control targets for the other 2, and vice versa). The tests we used were texture segregation, conjunction search and identification in contexts that might generate illusory conjunctions, perception of words containing the target letters, and target localization. The results have not yet been analyzed in detail, but they suggest that the perceptual learning that progressively speeds search and reduces the slope of search functions against display size is highly specific to the particular search task. There is little change in subjects' ability to detect boundaries between an area containing the target letters and an area containing distractors in a texture segregation task; there is little decrease in the dependence of identification on localization (which is normally found for simple feature targets, Treisman & Gelade, 1980); and search improvements with upper case letters generalize only partly to search for the same letters in lower case.

The test for illusory conjunctions gave an unexpected result before practice: we found no evidence for illusory conjunctions for parts of shapes. For example, subjects did not form illusory R's from P's and Q's or E's from F's and L's. We were therefore unable to test whether these illusory conjunction errors decrease with automatization. The absence of illusory interchanges suggests that letters may actually be more integrally coded than we had thought, even before practice at search begins (see Treisman & Souther, 1986, for other evidence consistent with this conclusion).

The word perception task was designed to test whether automatic detection of individual letters makes it more difficult to read whole words that contain those letters. The subjects run by Schneider and Shiffrin (1977) in multiple search sessions complained that practice at search made it difficult to read the newspaper because all they could see were the targets they had learned to detect. We found, however, no difference at all in the speed of lexical decision between words containing the target letters and words containing control letters.

The second study of perceptual learning, currently in progress, uses arbitrary shapes made of 6 straight line segments joining dots in a 3 by 3 matrix (Figure 4). Again subjects practice search for four of these targets over 16 sessions and are tested (both before and after practice) on their own four targets, on four control shapes (which are the targets for another group) and on four of the twelve shapes that are used consistently as distractors. The tests we used for transfer effects of perceptual learning are tests of detection of 3-line parts within the whole 6-line shapes (to see whether practice results in a more unitary wholistic representation); of mental rotation (to see again whether practice makes a unifed perceptual shape which is easier to rotate as a whole); of apparent motion (to see whether practice makes the lines of a shape easier to match in parallel across successive displays, when the target is embedded in other random lines that do not move coherently).

III. Attention as Facilitation or Inhibition

Elizabeth Beiring, Daniel Kahneman and I have tried to devise tests to distinguish how attention has its selective effect on perception and response. We have given two spatial cues just before a target display: each end of a red line signals the two locations where a target might occur and each end of a green line signals the two locations where a distractor might occur. The task is a choice response to E vs F in the target location; the one distractor is also an E or an F. The critical information about the effect of the cues comes on a small proportion of "probe" trials on which 7 X's are presented in a circular array (see Figure 5) and one target letter, which the subject must classify regardless of its position relative to the red and green cues. We compare the red and the green cued locations with a non-cued location equidistant from each. If attention facilitates perception and/or response to a target in the cued location, response times on probe trials should be faster when the letter is in the cued than in the control locations. If attention also (or instead) inhibits likely distractor locations, response times on probe trials should be slower when the letter is in an expected distractor location relative to an uncued control location. So far the results in this paradigm suggest that attention selects entirely by facilitating information from a target location.

There is little or no evidence of inhibition for distractor locations. We will run some further studies to see whether this conclusion is specific to a low load display (two letters only) in which selection is likely to be mainly at the response level, or whether it generalizes to a high load condition, where selection is more likely to affect perception as well as response.

IV. Memory for Non-Verbal Stimuli

1)Iconic memory

Marcia Grabowecky completed her M.A. thesis on three studies of iconic memory for conjunctions of color and shape. She presented colored letters at 8 locations in a circular array and cued which one should be reported, by presenting a white dot just outside one of the letter locations, at different intervals relative to the onset of the display (from 0 to 1000 msec.). In one condition, subjects reported only the color of the cued letter; in another condition they reported only its shape; and finally in a third condition they reported both its color and its shape. If conjunction information is present at any stage, we predicted that the probability of getting both correct on conjunction report trials should exceed the product of the probabilities of getting the color correct and of getting the shape correct. On the other hand if color and shape are registered independently, the conjunction information might take time to emerge, or might never emerge if attention is not focused on the correct item in time (i.e. if the cue is presented late relative to the display). Marcia found that the results fitted the independence prediction at all intervals tested. The result is consistent with the prediction from feature integration theory, that feature are initially registered independently and that they are combined only through focused attention. It rules out the alternative possibility that conjunction information (e.g. "red T-ness" or "Q-like blueness") is initialy present but is rapidly lost unless attention is focused to maintain it.

2)Implicit and explicit memory for visual patterns

Gail Musen is doing her PhD. thesis under my supervision. She is testing memory for visual patterns (made of five connected straight line segments) both by a direct and explicit memory task (recognition of learned patterns presented randomly mixed with new distractor patterns) and by an indirect measure of implicit memory (looking for a reduced perceptual threshold for the learned patterns when they are presented for brief durations and masked with random noise patterns). Previous studies measuring memory for words have shown that these two tests seem to rely on different and independent memory traces. The question Gail is testing is whether this separation depends on the use of stimuli which are already well learned and presumably have some representation in a "semantic memory network" so that the implicit memory test might depend on priming of semantic memory nodes and explicit memory on some separate "episodic memory" trace. If so, the non-verbal memory tests for perceptual priming and for recognition memory should not show independence early in learning, although they might do so after extended practice.

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Publications prepared during first year of AFOSR grant

Two papers have been accepted for publication in 1988:

Treisman, A., & Gormican, S. Feature analysis in early vision: evidence from search asymmetries. Psychological Review, in press.

Treisman, A. Features and objects: the fourteenth Bartlett memorial lecture. Quarterly Journal of Experimental Psychology, in press.

Two chapters will appear in edited books:

Cavanagh, P., Grüsser, O.J., Ramachandran, V.S., Treisman, A., & Van der Heydt, R. The perception of form: striate cortex and beyond. In Spillman, L., & Werner, J. (Eds.), Neurophysiological Foundations of Visual Perception. Academic Press.

Treisman, A. L'Attention, les traits et la perception des objets. In Andler, D. (Ed.), (title not yet available).

Invited lectures and conference talks:

Fourteenth Memorial Sir Frederic Bartlett lecture on "Features and Objects", given to the Experimental Psychology Society, London, England, Jan. 6, 1987.

Two talks on "Preattentive Processing in Vision" and "Attention and Object Perception", to the Bat Sheva Seminar on Selective Attention, Jerusalem, Israel, Jan. 7-16.

Colloquium to Cognitive Science program at University of California, Berkeley, Feb. 1987.

Colloquium to Psychology Department, Stanford University, on "Features and Objects", Feb. 1987.

Talk to Smith Kettlewell Institute, San Francisco, Feb. 1987. and discussions with Ken Nakayama.

Invited paper in symposium on Vision organized by NRC Committee on Vision in Washington, DC, March 1987.

The Fitts Lectures (jointly with D. Kahneman), six lectures on "Attention, Features, and Objects", at the University of Michigan, May 1987.

Invited talk to a conference on Cognitive Science at Cérisy-La-Salle, Frane, June 1987.

Invited paper to a conference on the Neurophysiological foundations of visual perception, Badenweiler, Germany, July 1987.

Invited paper in Presidential Symposium on Attention at the Neurosciences conference in New Orleans, Nov. 1987.

Discussion and consultation with Alan Gevins on his research on evoked potentials in information-processing.

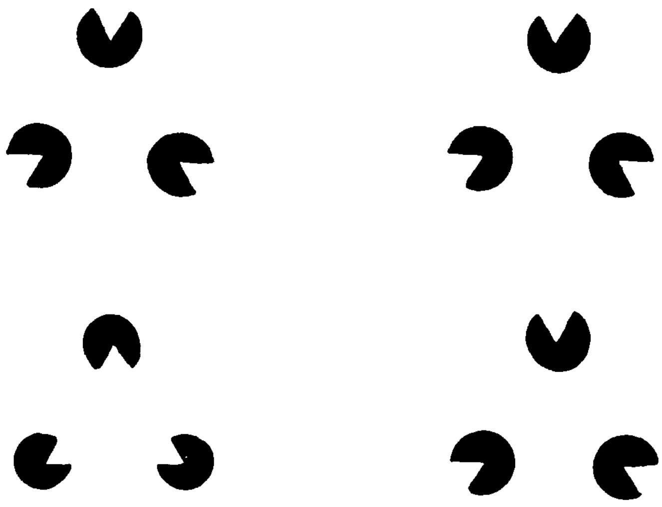

Figure 1: Search for subjective triangle among pacman-triple distractors.

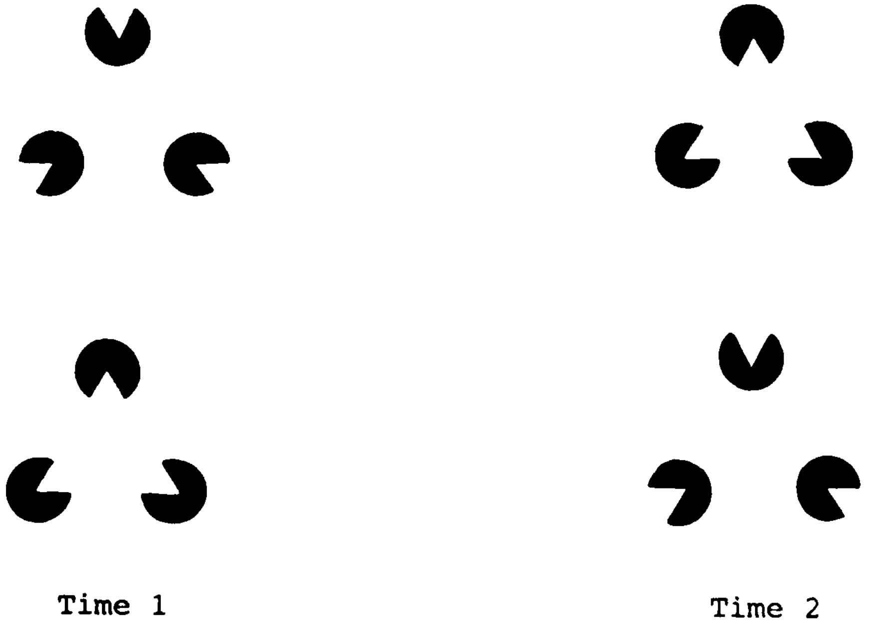

Figure 2: Apparent movement displays.

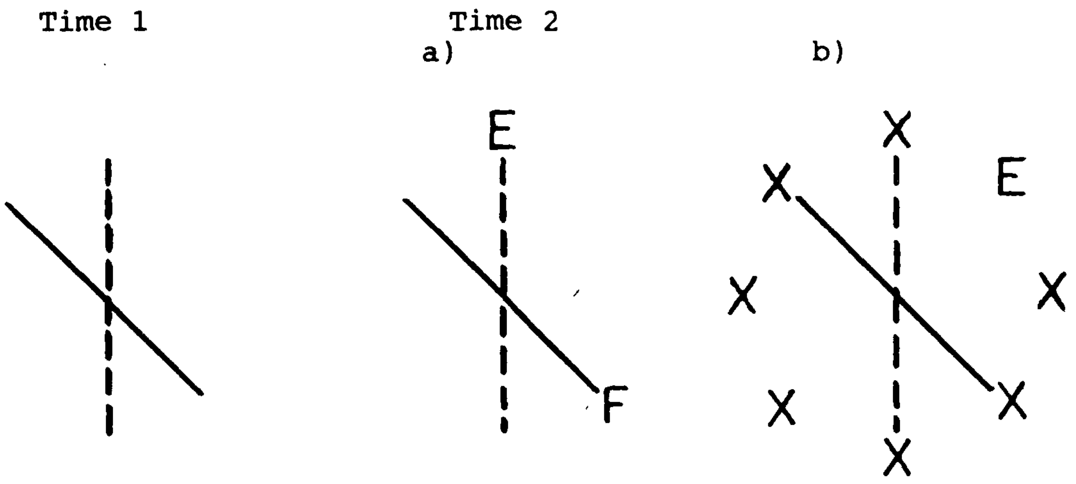

Figure 5: Examples of displays used to distinguish facilitation from inhibition in selective attention to pre-cued locations. (a) Normal trial; (b) Probe trial.

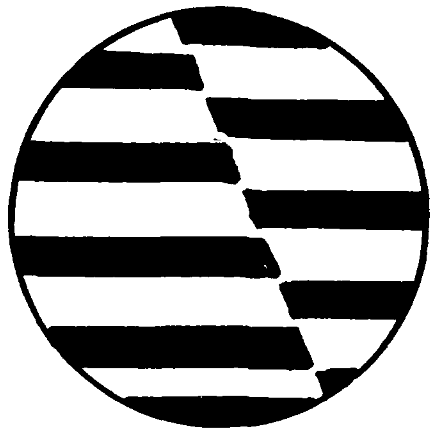

Figure 3. Subjective contour produced by abutting lines.

Figure 4. Examples of shapes used in second perceptual learning study.

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